Joints of the Upper Extremity

Introduction

In this second installation of the Upper Extremity we focus on the joints—the details of the anatomy left out of the first lesson and the pathologic states associated with those joints. The emphasis is on the shoulder—rotator cuff anatomy, rotator cuff physical exam testing, and shoulder dislocations—with a hefty discussion on the carpal tunnel and carpal tunnel syndrome, and closing with some fractures of the wrist and hand. Elbow joint diseases usually involve the nerves as they cross the joint, and so are reserved for MSK #3: *Nerves of the Upper Extremity.*

Shoulder # 1: Rotator Cuff Injuries

A brief review of the anatomy from MSK 1: *Anatomy of the Upper Extremity* is provided for context. The **supraspinatus** originates in the superior (supra) region of the posterior scapula, runs over the over the top of the glenohumeral joint from the back, and inserts on the lateral humerus. It is innervated by the suprascapular nerve. Visualize this muscle as originating on the posterior side of the scapula, on the edge of the scapula that is most medial, in the middle of the back. When it contracts, it lifts the lateral humerus toward the top scapula, lifting the arm up and out—**abduction** from 0°–15°. The **infraspinatus** originates in the inferior (infra) region of the posterior scapula, and runs under the spine of the scapula, over the back of the glenohumeral joint, to insert on the lateral slightly anterior aspect of the humerus. It is also innervated by suprascapular nerve, and when it contracts it pulls the lateral humerus, rotating it backwards. Let your right arm hang at your side, loose. Flex 90 degrees at the elbow, with your thumb up in the air. Keeping your elbow against your side, rotate your hand away from your body. This is **external rotation** of the shoulder. That is what the infraspinatus does. **Teres minor** has the same function as infraspinatus, but from a different nerve, the axillary nerve. The only rotator cuff muscle originating on the anterior scapula is the **subscapularis,** innervated by the subscapularis nerve. It inserts at the medial humerus. When it pulls, the front of the humerus is rotated inward toward the body. If the elbow were flexed, the hand would move toward the body. This is **inward rotation**.

MUSCLE	NERVE	ACTION
Supraspinatus	Supraspinatus nerve	Abduction 0°–15°
Infraspinatus	Supraspinatus nerve	External rotation
Teres minor	Axillary nerve	External rotation
Subscapularis	Subscapularis nerve	Internal rotation

Table 2.1: Rotator Cuff
Muscles, innervation, and action in review.

The external muscles of the shoulder are the large muscles. They move the shoulder. The rotator cuff muscles stabilize the shoulder. But when one of these muscles cannot do what it's supposed to, even though the big muscles can still make big movements, the stabilization fails, which can provoke symptoms. The patient usually feels pain—not from the injured rotator cuff muscle, but from the shoulder joint muscles compensating. The physician assesses for weakness. The physician will isolate the rotator cuff muscles by putting the arm into positions that prevent the big muscles from helping. **The dysfunction is defined by what the patient cannot do.** Since all muscles pull, a dysfunctional muscle will result in **weakness**. The weakness will be sensed when the patient attempts to do what the muscle does. An injured muscle will present with weakness. An injured nerve to an intact muscle will present with weakness. Pain with weakness is often an acute tear. Weakness without pain is either a nerve injury or an old tear. Pain without weakness is impingement syndrome.

Patients present with pain because of **impingement syndrome**. Impingement syndrome occurs because of compression of a tendon within the glenohumeral joint. The most commonly affected is the **supraspinatus** tendon, because the space the tendon travels through is smallest, and where impingement occurs most easily. Impingement syndrome presents with **pain without weakness**. Having impingement syndrome is a risk factor for tendon rupture. **Tendon tear** will present with both **weakness and pain**. Tendon tears are either a product of **acute trauma** (falling on the shoulder), ongoing impingement syndrome, or chronic degenerative changes in patients taking fluoroquinolones.

Shoulder #2: Rotator Cuff Physical Examination

Specific exam maneuvers are used to isolate specific muscles of the rotator cuff for assessment. Pain is a useful finding. Weakness is what you are after.

An **internal rotation lag test** assesses specifically for the **subscapularis**. The test is performed by placing the elbow in 90° flexion, with the arm behind the back, fist in contact with the back. The examiner attempts to pull the arm off the back while the patient resists. The test is positive if the patient **fails to resist motion**. Because a strong examiner can obviously generate more force than an isolated subscapularis, the test is positive only relative to the opposite side.

The composite test, the **external rotation resistance test**, assesses the infraspinatus. The arm is placed in neutral position, the elbow flexed to 90°, and the patient asked to externally rotate (push the hand outward) against resistance. Pain or weakness indicates an issue with the infraspinatus. Teres minor is not assessed.

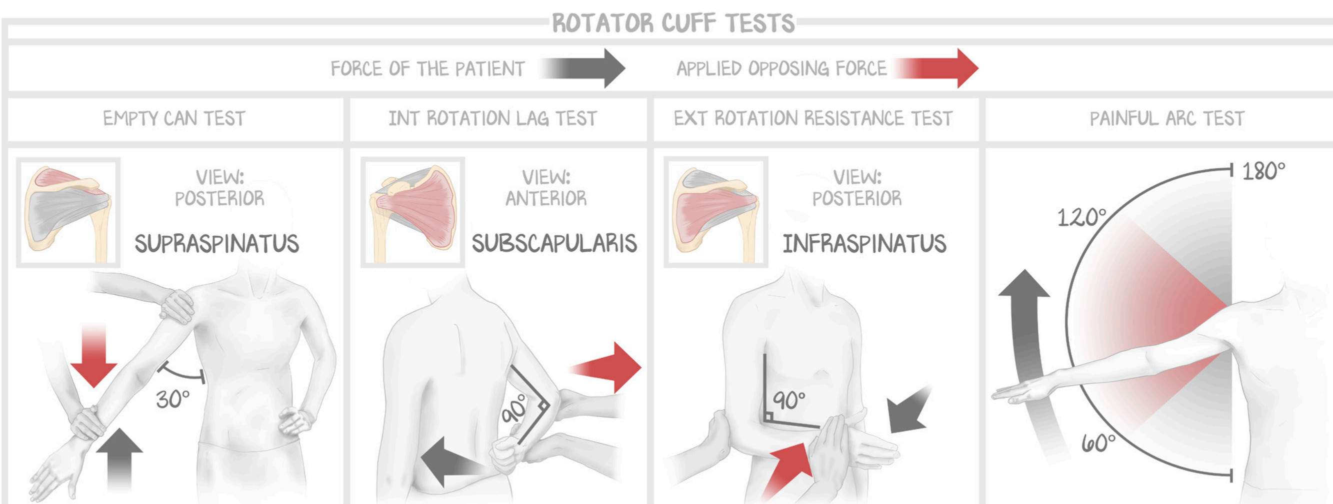

Figure 2.1: Tests for the Rotator Cuff
A visualization of the text that surrounds this figure.

The **empty can test** is used to assess the **supraspinatus**. To isolate this muscle, rotate the patient's hand so that the thumb is toward the ground (as if they were pouring out a can of beer). Have the elbow fully extended, the shoulder abducted to about 30°. Downward pressure is applied by the examiner while the patient abducts. Pain and weakness are a positive test.

The pain provocation test, the **painful arc test**, asks the patient to **abduct** their shoulder from 0° to 180°. The arc test assesses the function of many muscles, but its goal is to assess **for pain between 60° and 120°**. Don't be tricked—even though the arc is from 0° to 15°, this test does not assess the supraspinatus, and even though abduction is through 120°, this test does not asses the deltoid. If there is pain between 60° and 120°, it is positive for either a **rotator cuff injury** OR an **impingement disorder**.

Shoulder #3: Shoulder Dislocations

There are two shoulder dislocations: anterior and posterior. It will be your job to keep them separated. In **both forms** of dislocation, the humerus falls out of the socket, and so the arm is closer to the trunk—**adducted**. This pushes the elbow into the ribs. The elbow flexes, the arm is bent. From here, the clues as to whether this is an anterior or posterior dislocation will come from the mechanism of injury and which way the humerus (and therefore the entire forearm and hand) is rotated. The muscles "in back" are the teres minor and infraspinatus. If they get stretched, they pull, and the humerus is pulled toward the patient's back, externally rotated. The muscles "in front" are the pectorals and subscapularis. If they get stretched, they contract, and pull the humerus toward the patient's front, internally rotating the humerus. We'll show you how to keep them straight.

An **anterior dislocation** is far **more common** than a posterior dislocation. It can happen in any mechanism of injury, such as a fall, sports injury, or car accident. If the humerus pops out of the socket and the head of the humerus moves forward, this means that the muscles "in front" relax while the muscles "in back" get stretched. All dislocations present with the elbow against the hip, adducted. But because the muscles in back get stretched, they contract against that stretch, and pull the humerus into **external rotation**. In an anterior dislocation, there may also be subsequent axillary nerve damage (see MSK #3: *Nerves of the Upper Extremity*).

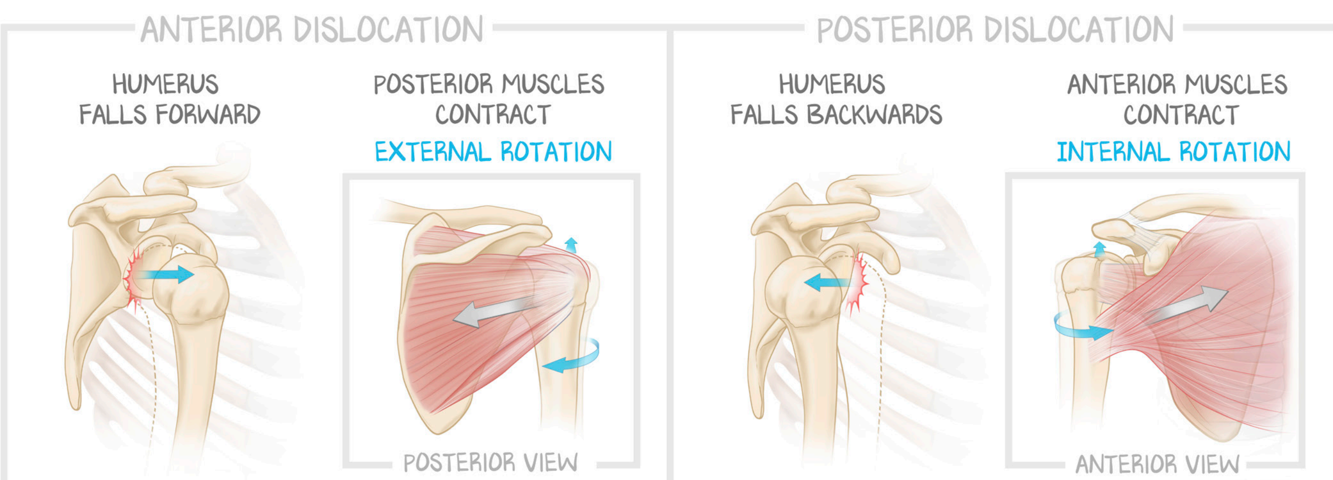

Figure 2.2: Shoulder Dislocations
With an anterior dislocation the humeral head falls forward. That stretches and activates the posterior muscles—teres minor and infraspinatus—which cause external rotation. With a posterior dislocation (just show the bones), the anterior muscles activate—subscapularis—and internally rotate the humerus.

A **posterior dislocation** is caused only by severe trauma—**epilepsy or lightning strikes** (think "electricity of the brain" or "electricity of electrocution")—and will have the opposite rotation to anterior. If the humerus pops out of the socket and the head of the humerus falls backwards, the pec major and subscapularis (the muscles in front) get stretched, and thus contract, **internally rotating** the humerus. The infraspinatus and teres minor relax.

DISLOCATION	AB/AD	ROTATION	MECHANISM
Anterior dislocation	Adducted	Externally rotated	Any trauma
Posterior dislocation	Adducted	Internally rotated	Electricity of the brain Electricity of electrocution

Table 2.2: Anterior vs. Posterior Dislocations

Elbow Pathology

The humerus has a lateral epicondyle and a medial epicondyle. The **lateral epicondyle** is the origin of the wrist **extensors**, the extrinsic muscles of the hand and wrist. The **medial epicondyle** is the origin of the wrist **flexors**, the extrinsic muscles of the hand and wrist. In **overuse** injuries, one of these epicondyles may become inflamed, leading to pain.

Lateral epicondylitis is called tennis elbow. It provokes tenderness on the lateral epicondyle and proximal wrist extensors. There is also pain when you induce contraction of the wrist extensors, as when a patient resists flexion of the wrist (by the provider) with active extension of the wrist (by the patient).

Medial epicondylitis is called golfer's elbow. It provokes tenderness on the medial epicondyle and proximal wrist flexors. There is also pain when you induce contraction of the wrist flexors, as when a patient resists extension of the wrist (by the provider) with active flexion of the wrist (by the patient).

Wrist #1: Carpal Tunnel Syndrome

The carpal tunnel is a region within the wrist through which structures from the forearm enter the hand. You don't have to understand everything about the wrist bones to get the clinically relevant carpal tunnel straight. Don't attempt to visualize what this looks like in three dimensions. See it as it exists where it matters—in the cross-section of the carpal tunnel. The tendons of the forearm muscles, the **tendons of the extrinsic muscles** of the hand, go through the carpal tunnel. The **median nerve** goes through the carpal tunnel. The carpal tunnel is defined by the immobile structures that surround it. With the palm facing up, the carpal bones—pisiform, triquetrum, hamate, capitate, and scaphoid—line the base of the carpal tunnel, the bottom. On top of the carpal tunnel is the **transverse carpal ligament**. This is a ligament that connects the carpal bones to one another. That means the carpal tunnel has rigid structures all around it, with squishy structures (nerves, tendons) running through it. If the structures within the tunnel get inflamed, they have nowhere to swell, and so will become compressed. If they swell too much and need to be released, it's the ligament that gets cut.

The median nerve runs through the carpal tunnel. In carpal tunnel syndrome, the median nerve gets compressed. Compression of the median nerve between the **transverse carpal ligaments** and the carpal bones causes loss of motor and sensation in the muscles and skin innervated by the median nerve distal to the carpal tunnel. The median nerve innervates **sensation of the palmar surface of the first, second, and third digits**. When the median nerve is compressed, sensory changes occur in these areas—numbness and tingling. However, the cutaneous sensation is **spared over the thenar eminence**. Sparing the thenar eminence is enough to cinch the diagnosis on a licensing exam—the palmar cutaneous branch of the median nerve branches prior to the carpal tunnel. This means that if the palmar aspect is affected, the lesion must be above the carpal tunnel, in the arm. Only in severe carpal tunnel is the motor function of the median nerve affected. The median nerve innervates the thenar (thumb) muscles. **Weakness of thenar muscles** and **thenar atrophy** indicate severe median nerve compression. The absence of these findings should not preclude the diagnosis of carpal tunnel syndrome, especially when faced with sensory findings.

A physician can induce symptoms by compressing the median nerve temporarily. The **Tinel sign** (pain or tingling when tapping the carpal tunnel with the wrist in extension) and the **Phalen maneuver** (90° flexion of the wrists causes tingling or pain from compression) are pathognomonic for the disease.

Symptoms typically worsen during sleep. Previous wrist fracture, obesity, diabetes, osteoarthritis, hypothyroidism, and pregnancy are risk factors. These make sense because the things that do the compressing or that take up space—fat, bones, edema—increase. But one that doesn't make much sense, and one that is probably the highest yield, is the tie between **carpal tunnel and rheumatoid arthritis**, where the carpal tunnel may be the first presenting symptom. The strongest risk factor for developing carpal tunnel is having rheumatoid arthritis.

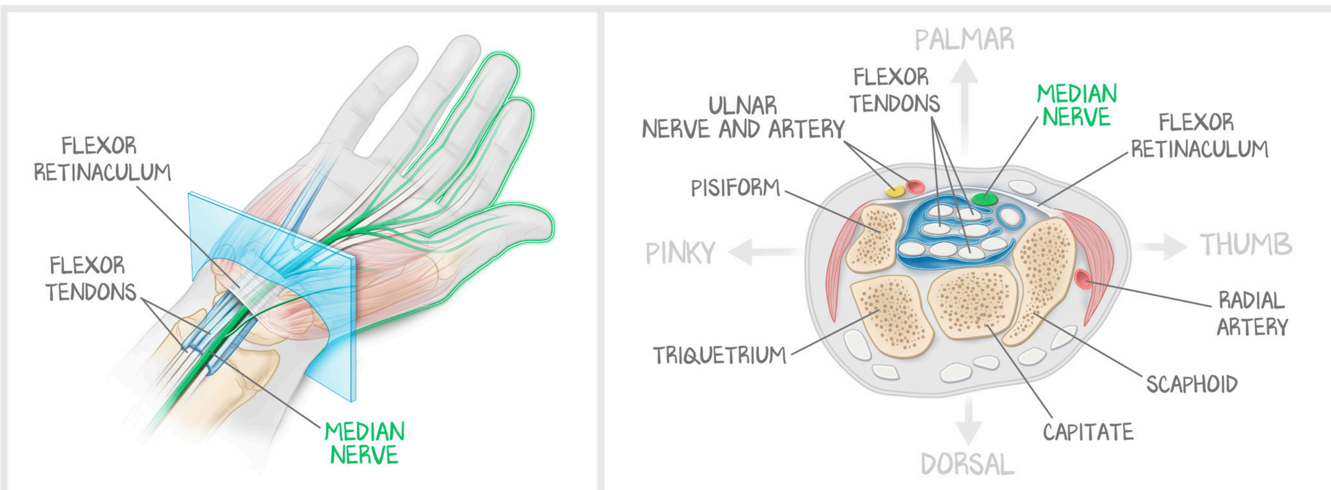

Figure 2.3: The Carpal Tunnel Wrist
A depiction of the wrist both for orientation of the coronal slice, and also to simplify the wrist—it is a place for tendons, nerves, and arteries of the hand to pass. A coronal slice of the wrist depicting where different structures pass, including the Guyon canal, the carpal tunnel, and the carpal bones.

Treatment for carpal tunnel syndrome varies by severity. First, rheumatoid arthritis should be ruled out with a rheumatoid factor. Then, assuming that diagnosis is not the cause, escalating therapies are NSAIDs, splints, and eventually facial release (cutting the ligament) surgically. You will not have to decide treatment at this stage in your training.

Wrist #2: Guyon's Canal Syndrome

Guyon's[1] canal syndrome is far more rare than carpal tunnel, but is so identifiable that we thought it worth including. It is the "other palmar nerve problem" that parallels carpal tunnel. The ulnar nerve runs through the wrist not within the carpal tunnel, but next to it, between the hamate and the pisiform bones. As carpal tunnel syndrome results from a compression of the median nerve, Guyon's canal syndrome results from an **ulnar nerve compression.** This is not the ulnar nerve lesion discussed in MSK #3: *Nerves of the Upper Extremity*, caused by damage of the ulnar nerve at the elbow. Instead, Guyon's canal syndrome is an ulnar nerve compression disease at the wrist, affecting the hand only. This condition presents in patients who are **cyclists**, induced by compression of the ulnar nerve by their handlebars. There is a sparing of ulnar nerve motor and sensation proximal to the wrist, proximal to the canal. Because the ulnar nerve innervates whatever the median nerve doesn't on the palmar

1. Named after the French Surgeon, Jean Casimir Félix Guyon, this eponym is pronounced closer to Gee-Yawn (hard G) than Guy On.

surface, ulnar nerve compression leads to **loss of motor function** (weakness) of **intrinsic hypothenar hand muscles only** (hypothenar muscles, adductor pollicis, interossei, lumbricals of 3 and 4) and a **loss of sensory function** of the superficial terminal branches, primarily affecting **digit 5** and **most of 4**. Cessation of cycling or padding the wrist with gloves can alleviate and even reverse the syndrome.

Wrist #3: Scaphoid Fracture

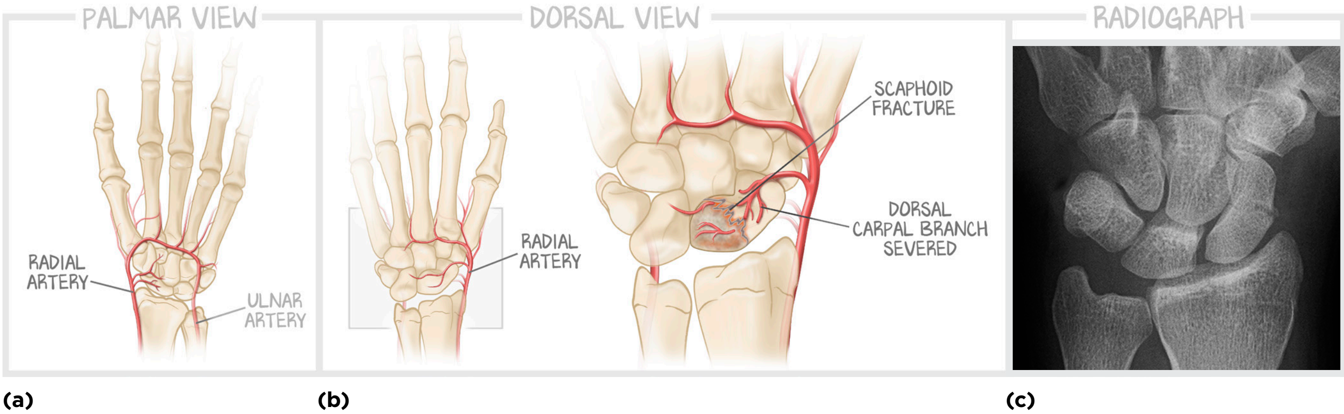

Figure 2.4: Scaphoid Fracture
(a) Arrangement of normal anatomy. (b) A fracture severs the arterial supply of the distal branch of the radial artery, which compromises the proximal pole of the scaphoid. (c) X-ray showing fracture of the scaphoid bone.

A scaphoid fracture is a fracture of the scaphoid of the hand. The classic presentation is a **fall on an outstretched hand** with the **wrist in dorsiflexion**. In this position, you land with your thenar eminence taking the impact on the ground. If elderly, the forearm bones break, giving way to the force. If young, the forearms don't give way, and the scaphoid takes the full force, and breaks. The problem with the scaphoid bone is the vascular supply coming from the radial artery and reaching across the scaphoid. This makes the radial-artery side of the scaphoid bone not prone to ischemia. But the proximal pole of the scaphoid, which is the most distal from the radial artery, is a **watershed area**. Compromise of the vascular supply by a scaphoid fracture compromises distal flow of blood to the proximal pole of the scaphoid. Not having a blood supply puts the bone at risk for **avascular necrosis**—the bone dies because the fracture severs the artery leading to a watershed infarct—and therefore **nonunion**. The patient will present with **pain in the anatomical snuff box** created between the extensor pollicis longus and extensor pollicis brevis (thumb tendons). The tricksy part of this diagnosis is that the initial X-ray may be negative, implying there is no fracture. As pain persists, however, a **repeat X-ray one week later** will show the **avascular necrosis**—the product of a missed fracture diagnosis. Don't let a "negative" X-ray the day of a fall deter you from the right answer.

Fractures #1: Greenstick and Torus Fractures—Compression and Tension Forces

Both greenstick and torus fractures are **incomplete breaks** that are caused by a compressive force exerted onto a bone. In a greenstick fracture, the fracture occurs on the tension side of the bone, across the bone from the source of compressive force. In a torus fracture, the fracture occurs on the compression side of the bone, on the same side as the compressive force. The clinical scenarios are very different, so they are not hard to separate, but the thing you will be tested on is commonly the mechanism of the break. If enough force is applied by either mechanism, there will be a complete break, and it will not be possible to tell from the X-ray alone which mechanism was activated.

FRACTURE	MECHANISM	WHERE FRACTURE	STRESS	EXAMPLE
Greenstick	Striking blow	Tension side	Bending stress	Blocking a nightstick
Torus	Twisting	Compression side	Axial stress	Adult twisting a child's arm

Table 2.3 Incomplete Fractures

Greenstick fractures. Bend your elbow and place your hand above your head, forearm parallel to the ground. This is how one blocks a blow from above. If that blow comes from a karate chop during a competition, the blow is deflected and no fracture occurs. If that blow comes by way of a 30-pound sledgehammer, both the radius and ulna will fracture. In this orientation, the compressive force is delivered first to the ulna, directed down toward your head, from the top of the bones (compression side) down. If the force is not strong enough to break the ulna, there won't be enough force to break the radius and neither bone will fracture (karate chop). If there is tremendous force, the ulna breaks and the remaining force also breaks the radius. But what greenstick fractures come down to is how they break. Bones break because they bend too far, the compressive force causing a **bending stress** (perpendicular to the bone). The force is delivered to the top of the bone, the force pushes through the bone, and the bone bows away from the stress. The bottom of the bone is stretched by the bowing, the top of the bone is compressed. Bones don't like being stretched. If there is sufficient force, that bowing breaks the bone, the break starting where there is the most stress on the bone—the stretched side. Because bowing of a bone stretches and fractures the stretched side, and because the side that is stretched is opposite the side of compressive force, the fracture occurs on the **tension side** of the bone. Greenstick fractures are what happens when there was enough force to induce bowing sufficient to break the bone a little, but not enough to make a complete break. Instead of a sledgehammer, envision a policeman's nightstick. With the extra length and a little more weight, a blow from above has enough force to break the ulna, enough remaining force to bow the radius, but not enough to break it entirely.

Torus fractures. Torus fractures occur because of **axial stress** (parallel to the length of the bone) and result in a fracture on the **compression side** of the bone. This happens when a child, with immature bone, falls on an outstretched hand. The force is delivered into the carpal bones and is translated into the radius and ulna. The weakest point of bone will be the part that fractures. In children, the most porous portion of bone is the metaphysis, which makes the metaphysis the point of least resistance. The fracture occurs in the metaphysis.

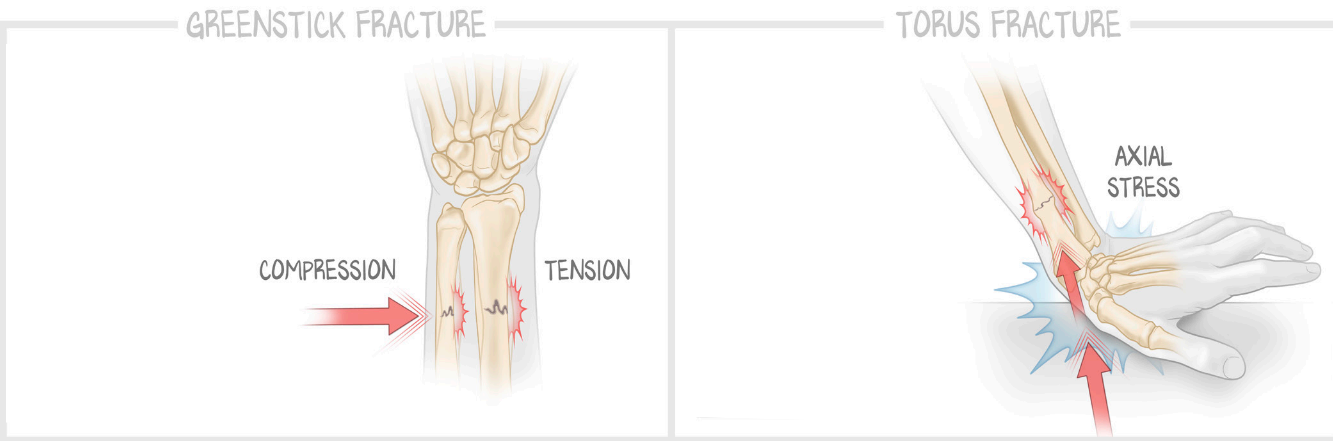

Figure 2.5: Greenstick and Torus Fractures
Greenstick fractures are incomplete fractures caused by a bending stress, such as blocking a nightstick. Torus fractures are incomplete fractures caused by the translation of axial stress, such as falling on an outstretched hand.

Radial head subluxation. While not a fracture at all, this is often tested against fractures in vignettes about trauma to a child. When an adult applies a yanking force on the wrist of a child, an immature annular ligament, which connected the radius and ulna, fails to hold the radius in place against the humerus. The injured arm will be held in an extended slightly flexed and pronated position. X-rays will not show fracture.

Metacarpal Neck Fracture, Boxer's Fracture

This is called a boxer's fracture but isn't caused during a round of gloved boxing. A bare-knuckle fighter will strike at an opponent, miss, and hit a wall. The hand is curled into a fist. The striking hand connects with the fifth digit first, and the force is applied to the smallest, frailest of finger bones. The **metacarpal fractures**. This presents with **focal bony tenderness** and an **X-ray with the fracture**. Any finger can break in this fashion, though classically it has been the fifth digit that breaks.

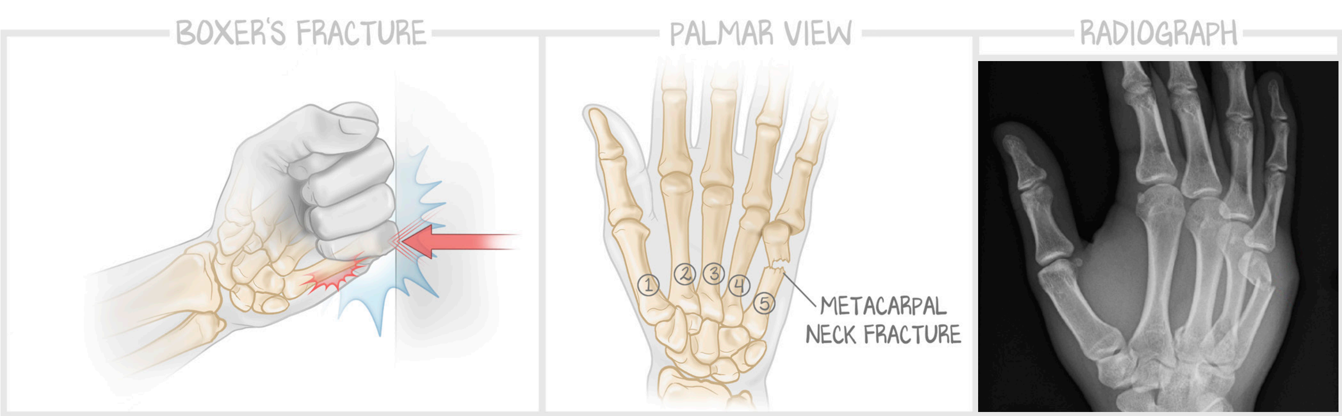

Figure 2.6: Boxer's Fracture
A boxer's fracture is caused by striking a solid object with a clenched fist. The 5th metacarpal is the smallest of the finger bones and the most easily fractured.

DISORDER	MECHANISM	NOTES
Impingement syndrome	Tendon of rotator cuff muscle impinged in shoulder joint	Supraspinatus most often affected, empty can test
Tendon rupture	Fluoroquinolones, trauma, or tendinopathy	Pain with weakness of muscle
Anterior dislocation shoulder	Any trauma, fall, or MVA	Arm is adducted and externally rotated
Posterior dislocation shoulder	Electricity	Arm is adducted and internally rotated
Carpal tunnel	Compression of median nerve at wrist	Sensory deficits of palmar digits 1, 2 and 3. Hypothenar atrophy, worsened by Tinel and Phalen maneuvers.
Guyon's canal	Compression of ulnar nerve at wrist	Cyclist with paresthesias and weakness of palmar aspect of the fourth and fifth digits
Scaphoid fracture	Fall onto outstretched hand	Avascular necrosis of bone, vascular supply
Greenstick fracture	Bending stress, tension side of bone	Nightstick blow blocked from above
Torus fracture	Axial stress, compression side of bone	Adult twisting child's arm
Boxer's fracture	Metacarpal neck fracture	Closed fist striking an immovable object

Table 2.4